AMTD: Mirror Substrate Design Trade Study

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Trade Study

Using Arnold Lightweight Mirror Modeler tool, evaluate candidate primary mirror substrate and assembly designs.

Assembly is Substrate, Support Structure & Interface Geometry

Evaluation Criteria

Mass	This Study
Thickness (volume)	This Study
First Mode Frequency (stiffness)	This Study
1.5 G Internal Stress	Future Study
Dynamic Launch Loads	Future Study
Thermal Deformation	Future Study
Thermal Time Constant	Future Study

This presentation is reporting on Substrate Trade Study only

Current Mirror Substrate Trade Study

Evaluated four mirror architectures:

- 4 meter solid
- 4 meter lightweight closed back
- 8 meter solid
- 8 meter lightweight closed back

Maximize First Mode Frequency as a function of:

- Depth
- Face sheet Thickness
- Rib Thickness
- Radius of Curvature

Constraints:	4 m monolithic	8 m monolithic
Mass	< 720 kg	< 10,000 kg
Thickness	< 500 mm	< 500 mm

Future Mirror Substrate Trade Study

We plan to expand the study to include:

- Open Back Substrates

And study Performance Criteria as a function of:

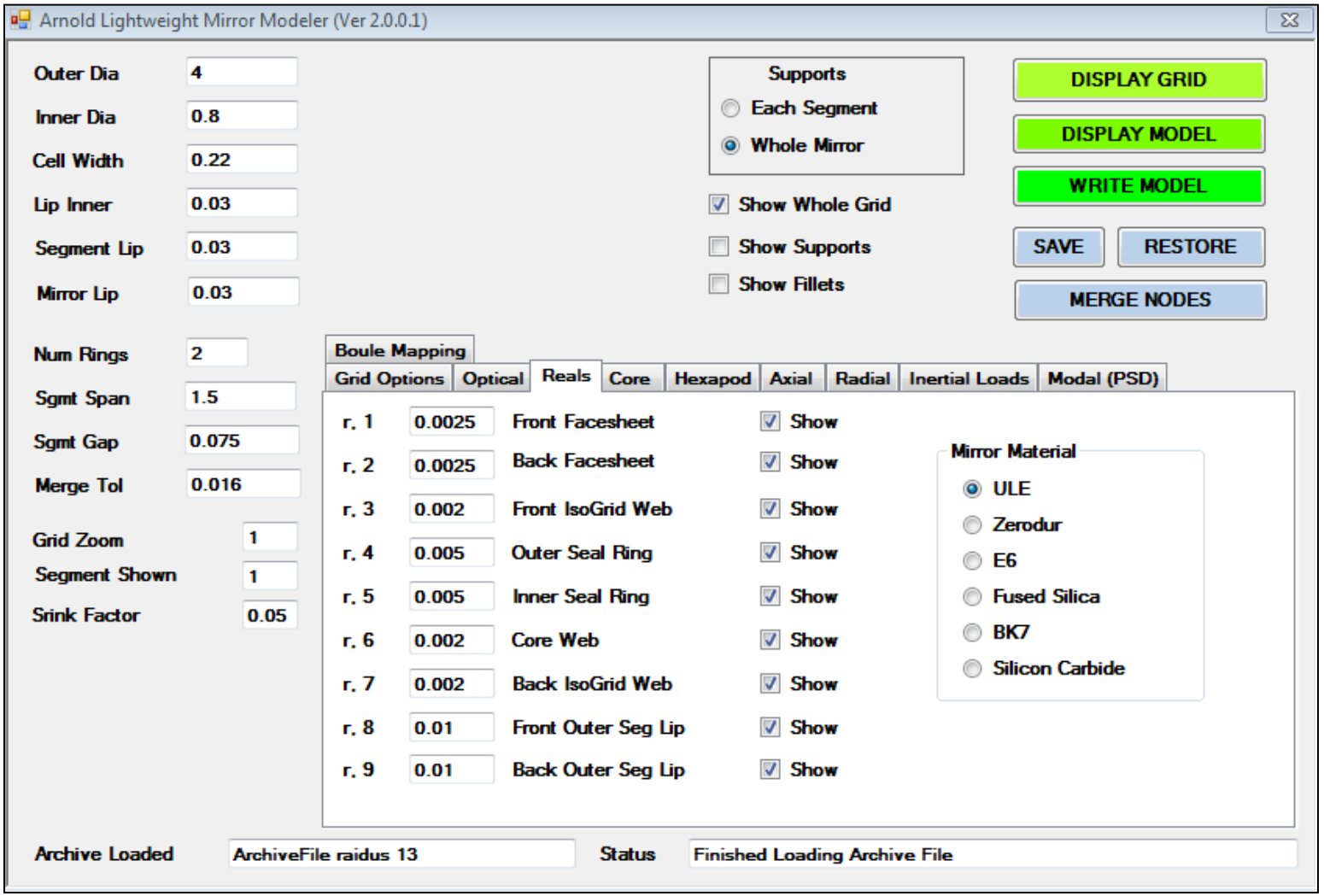
- Depth
- Face sheet Thickness
- Rib Thickness
- Radius of Curvature
- Material Choice
- Material Property Variation
- Mount Interface (3, 6, 9 point)
- Backing Structure Design

Design Process

Defining dimensions on left & check boxes for design elements

Design Process

Specify “reals” or real constants used by Ansys

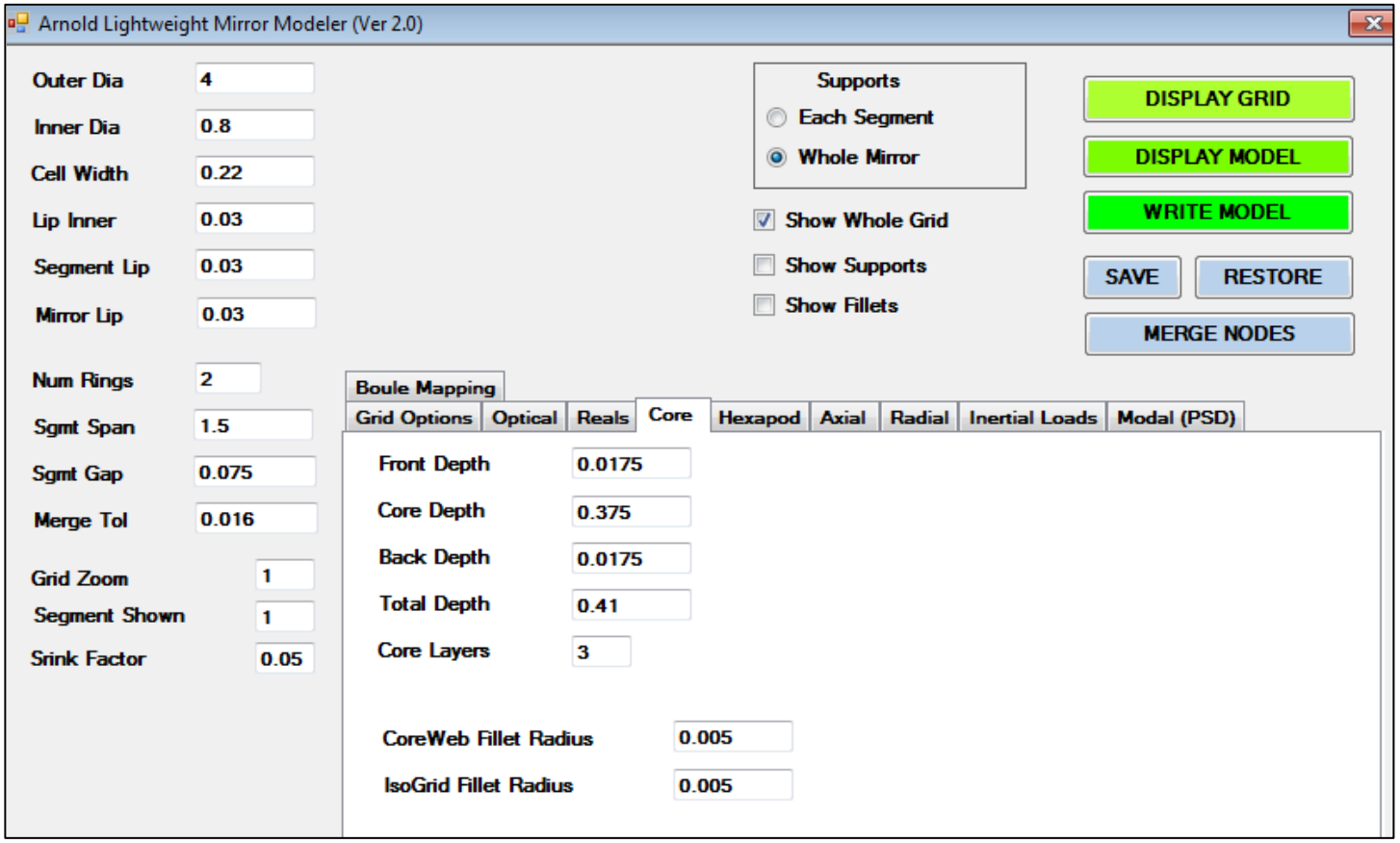


Design Process

Core Specification has its own tab.

Core depth is total core thickness divided by number layers.

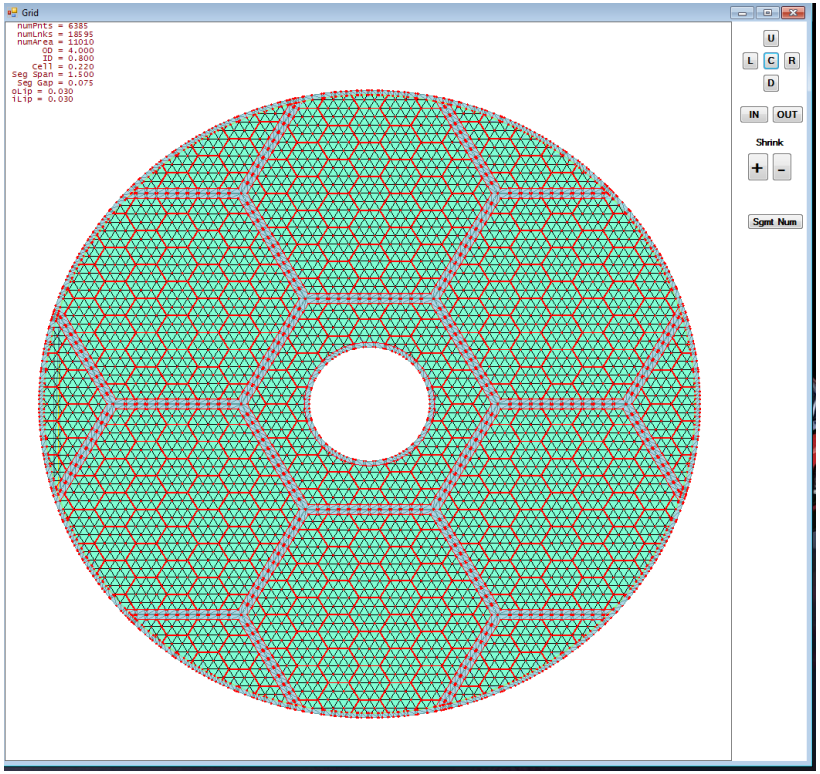
Front & back depths include facesheet thickness & pocket depth.



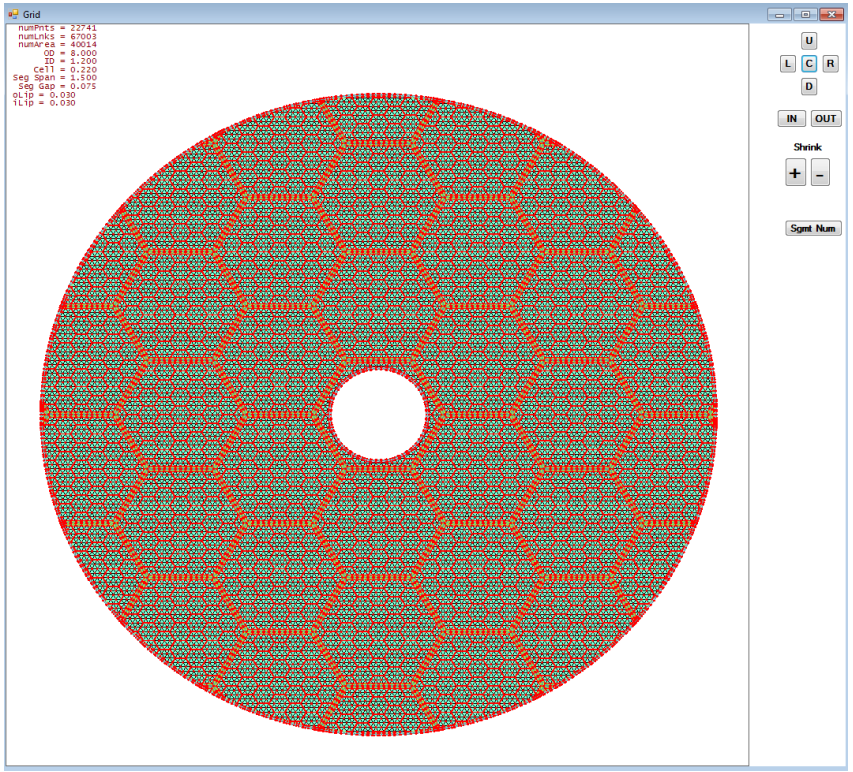
Grid View

Grid view shows internal core segments, lips, cells, and isogrid

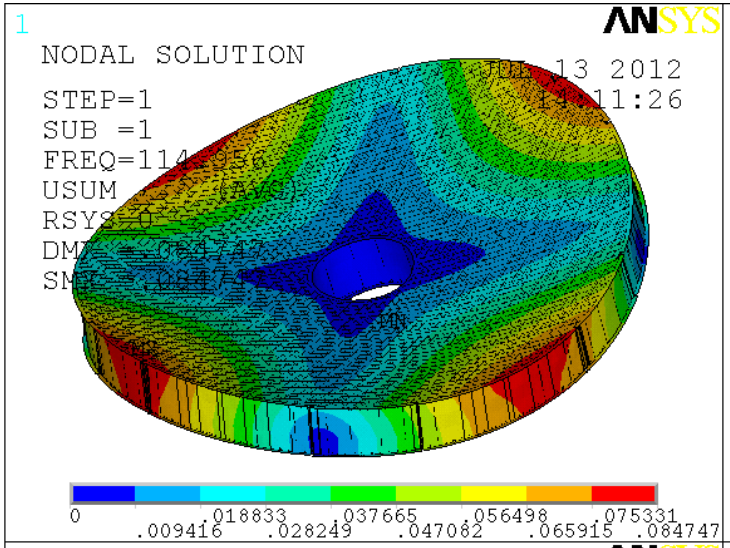
4 meter Design

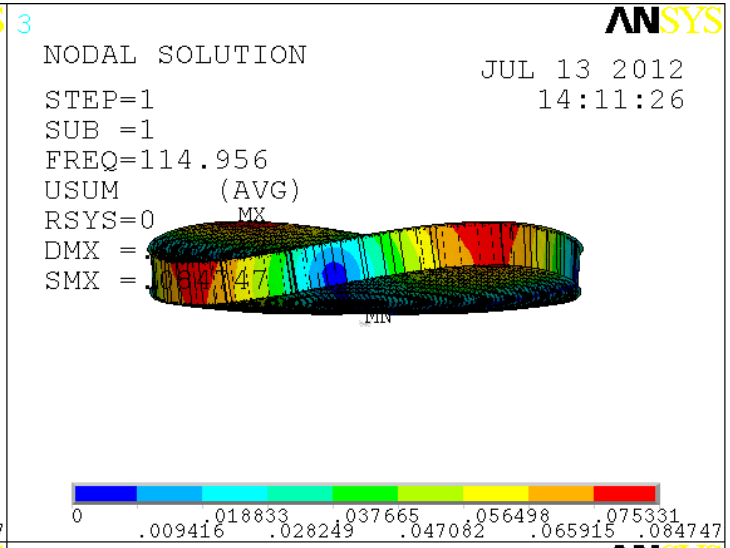


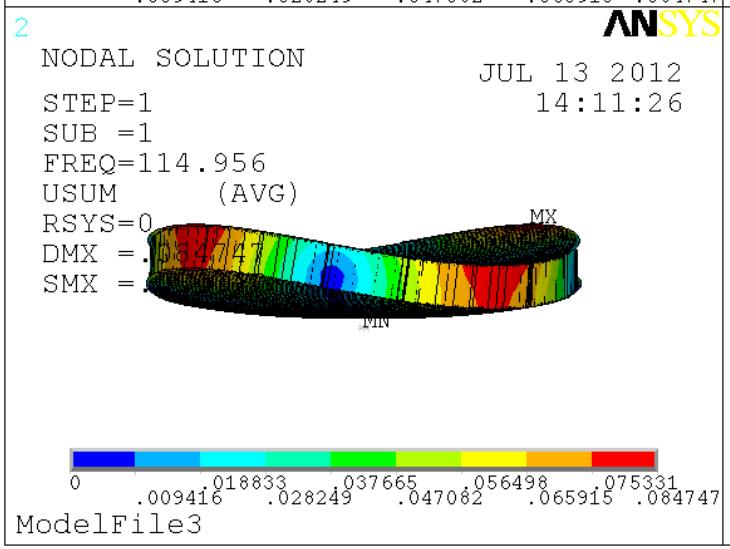
8 meter Design

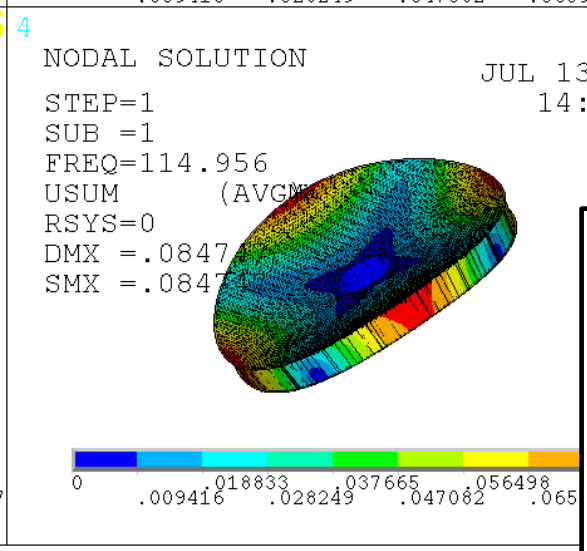


ANSYS performs Modal Analysis









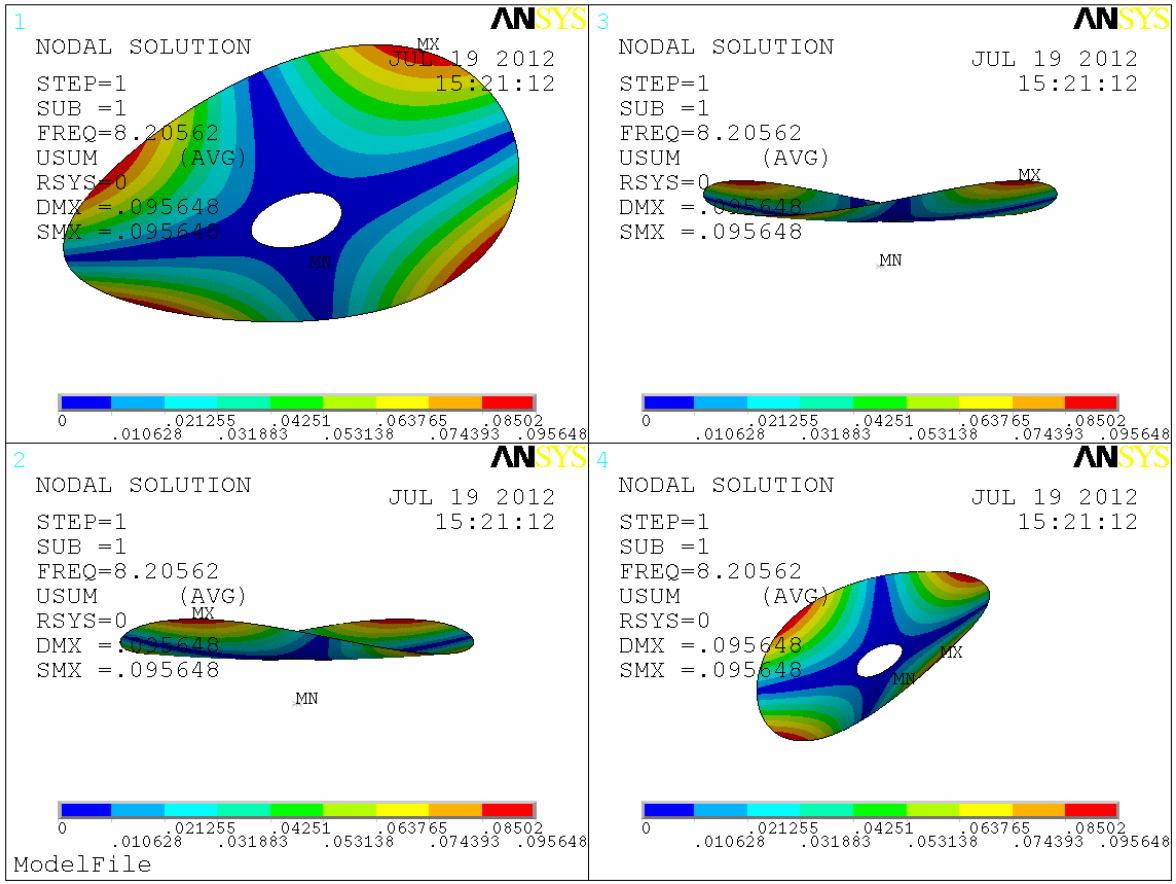
SET	TIME/FREQ
1	124.48
2	124.77
3	199.39
4	257.85
5	275.88
6	321.22
7	321.60
8	350.07
9	350.08
10	350.33

Trade Study Concept #1: 4 m Solid

Design:

Diameter	4 meters
Thickness	22 mm
Mass	595 kg
First Mode	8.2 Hz

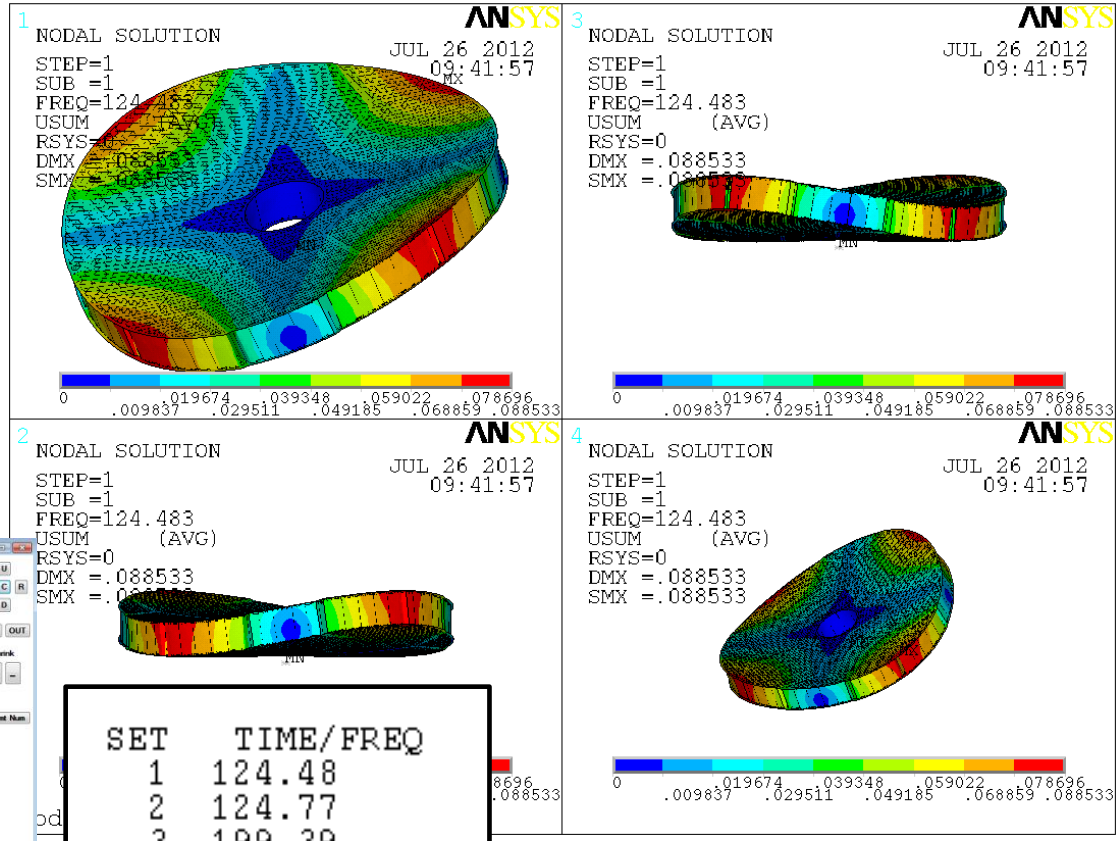
SET	TIME/FREQ
1	8.2056
2	8.2056
3	19.724
4	19.728
5	34.433
6	34.433
7	52.164
8	52.164
9	72.825
10	72.825

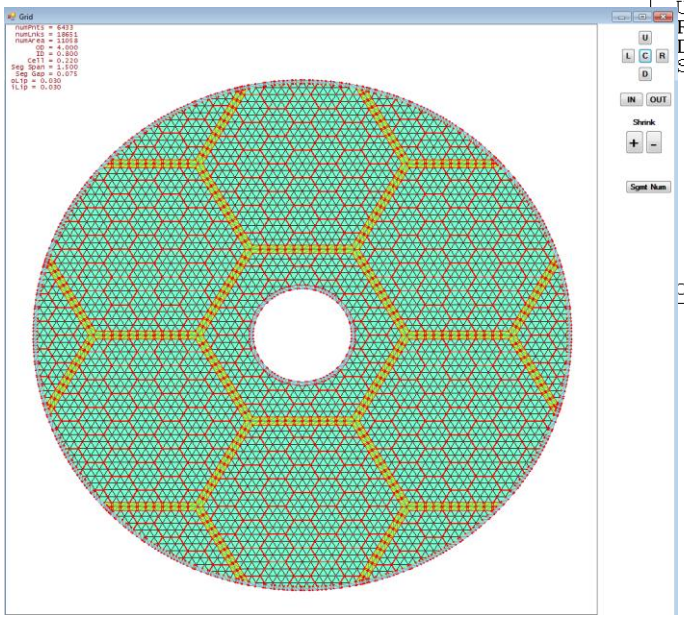


Trade Study Concept #2: 4 meter Lightweight

Design:

Diameter	4 meters
Thickness	410 mm
Facesheet	3 mm
Mass	621 kg
First Mode	124.5 Hz





SET	TIME/FREQ
1	124.48
2	124.77
3	199.39
4	257.85
5	275.88
6	321.22
7	321.60
8	350.07
9	350.08
10	350.33

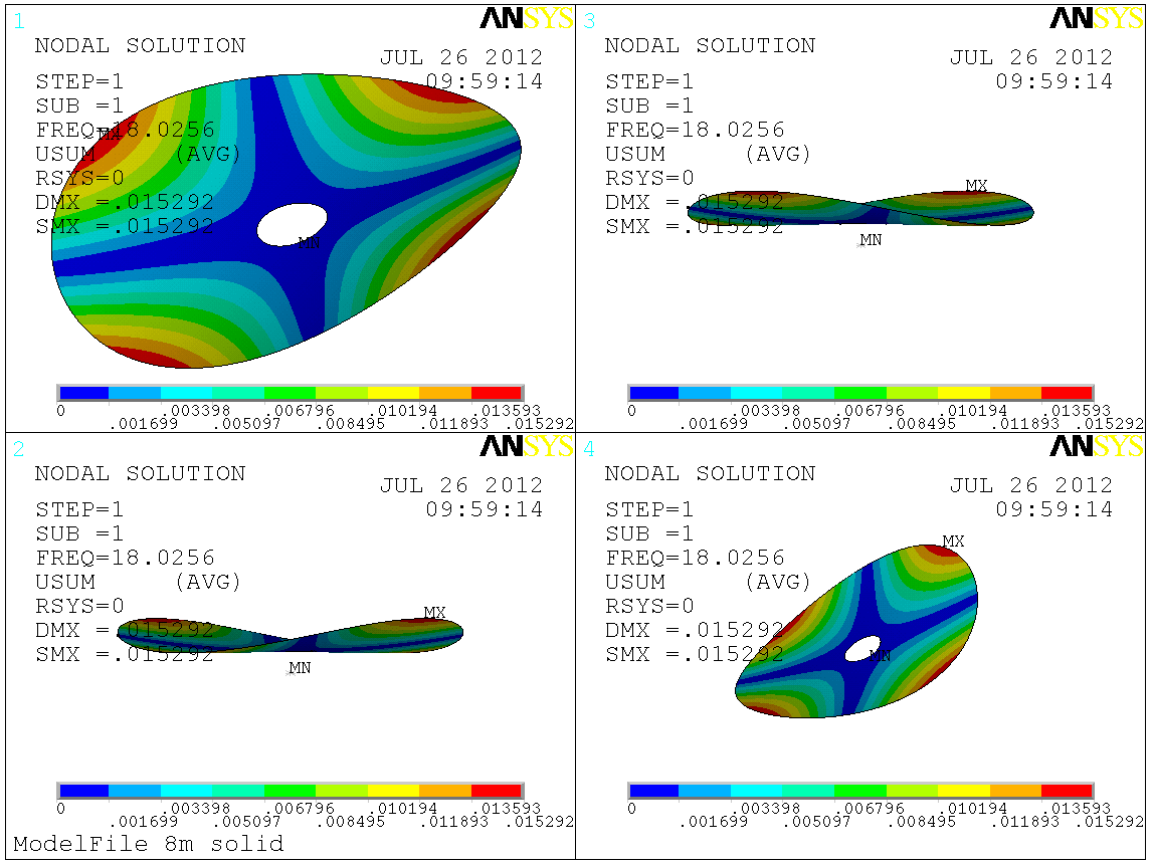
Trade Study Concept #3: 8 meter Solid 22 MT

Design:

Diameter	8 meter
Thickness	200 mm
Mass	21,800 kg
First Mode	18 Hz

Same as ATLAST Study

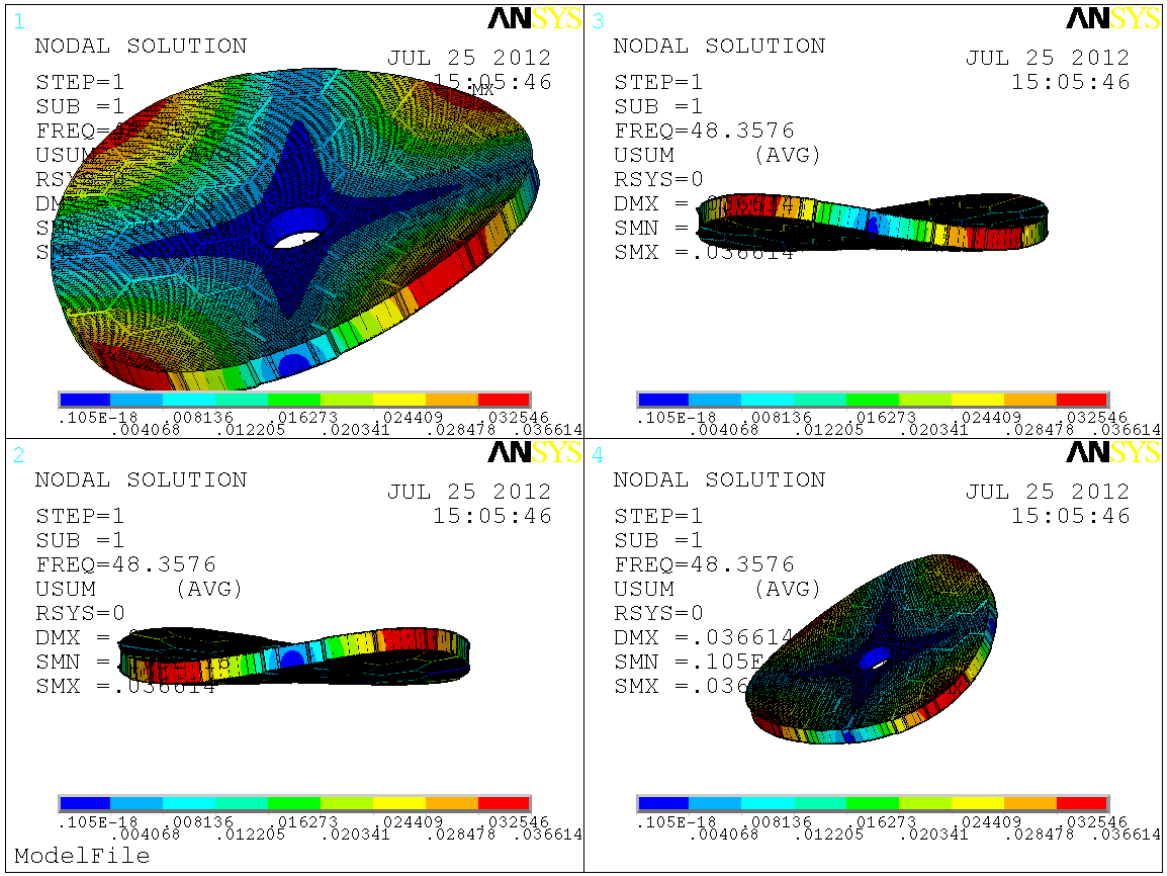
SET	TIME/FREQ
1	18.026
2	18.035
3	42.449
4	42.452
5	47.827
6	74.041
7	74.045
8	75.174
9	75.176
10	112.96



Trade Study Concept #4: 8 meter Lightweight

Design:

Diameter	8 meter
Thickness	510 mm
Facesheet	7 mm
Mass	3,640 kg
First Mode	48.4 Hz



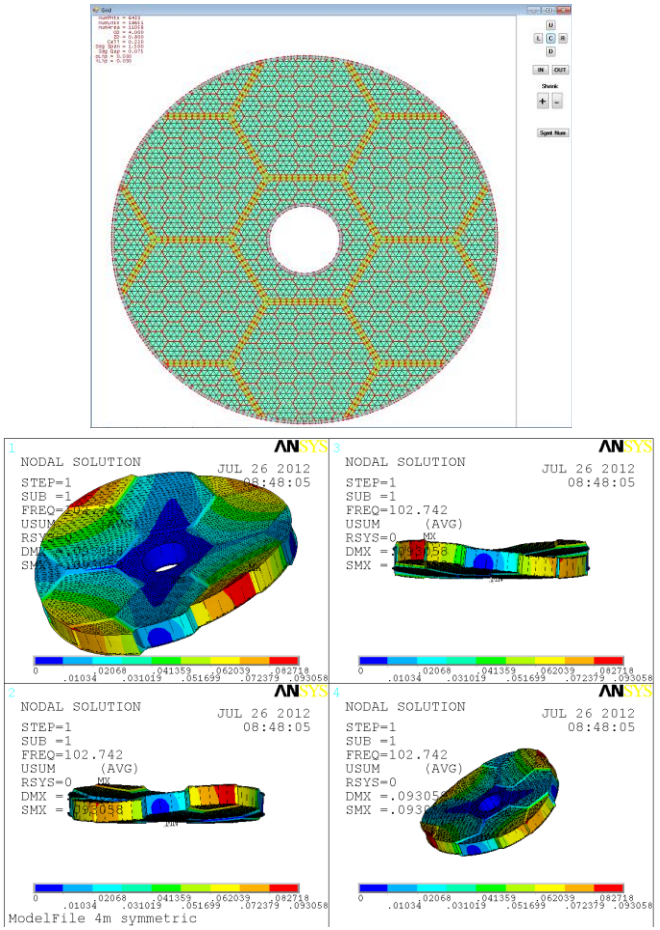
Parameter Trade Studies

4 meter

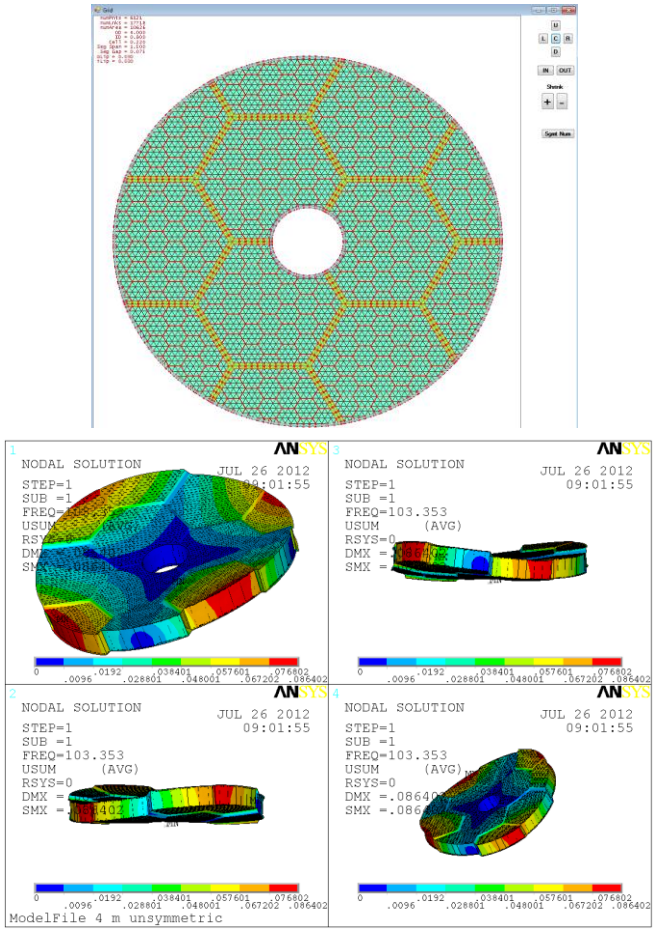
Symmetric vs. Offset

For a 4 meter, 310 mm thick mirror substrate, there is no observable difference between symmetric and off-set

Symmetric (103 Hz)

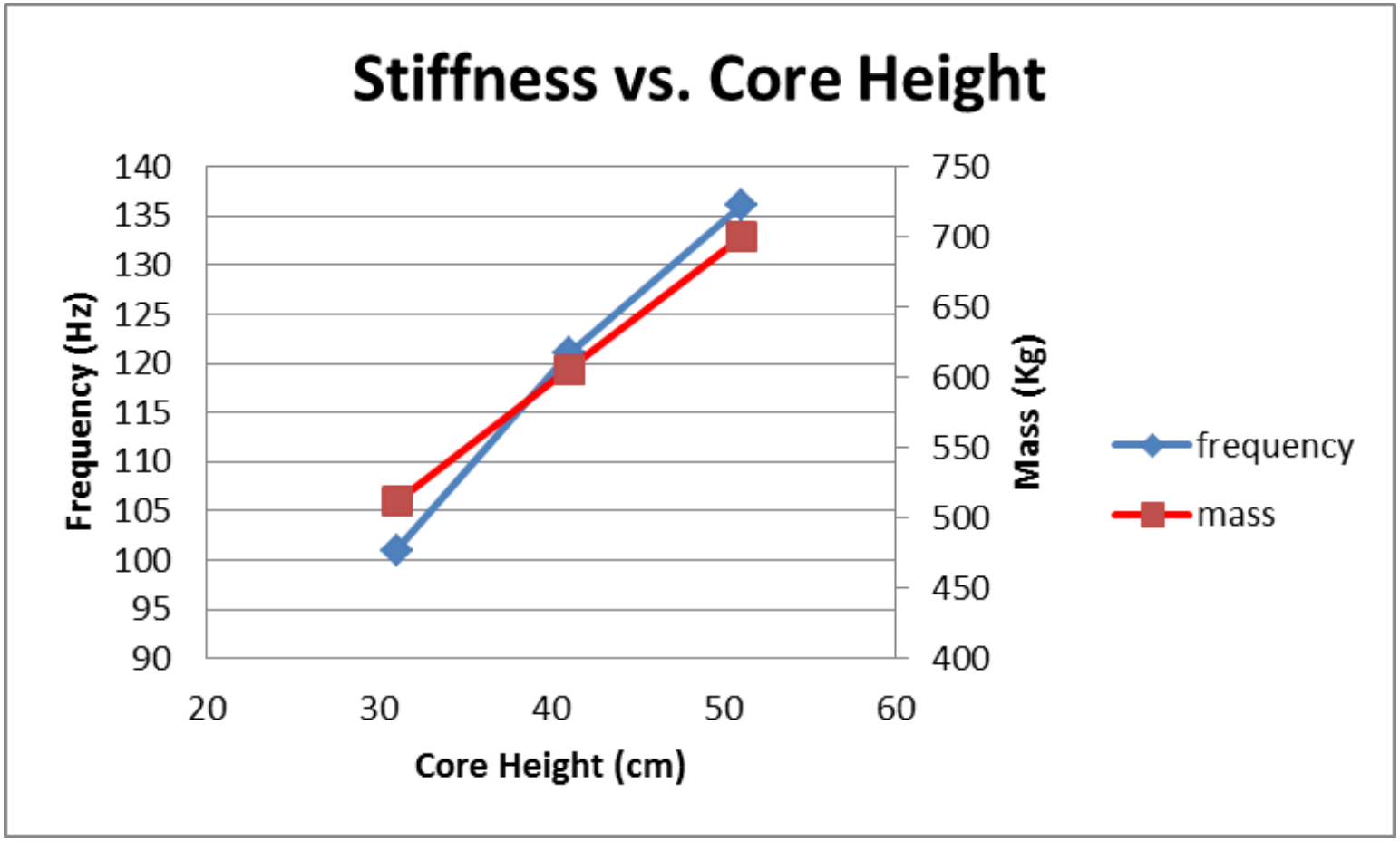


Offset (103 Hz)



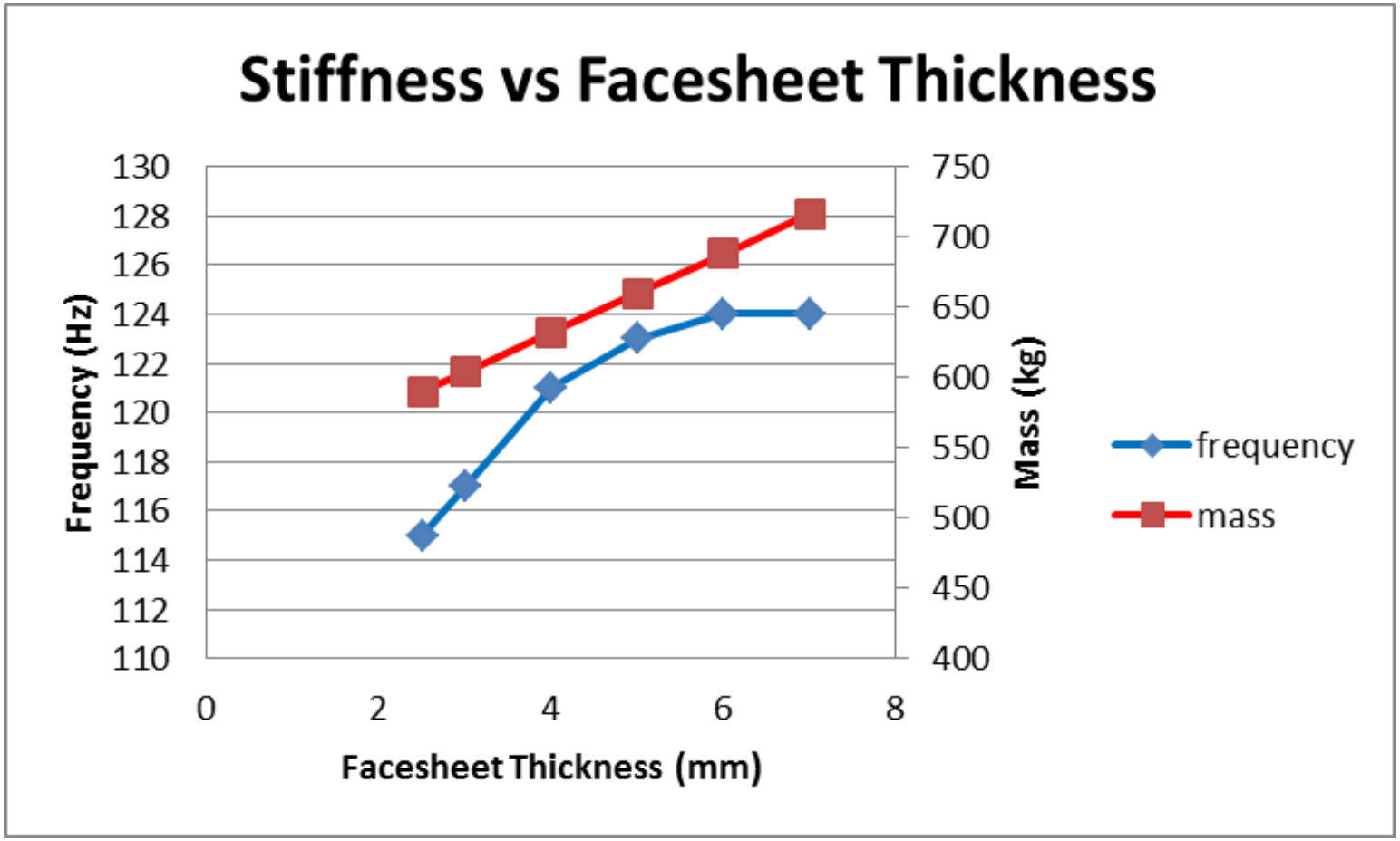
4 meter Stiffness & Mass vs Core Height

As expected, Core Depth has the greatest impact on stiffness; the deeper the Core the Stiffer and more Massive the Substrate.



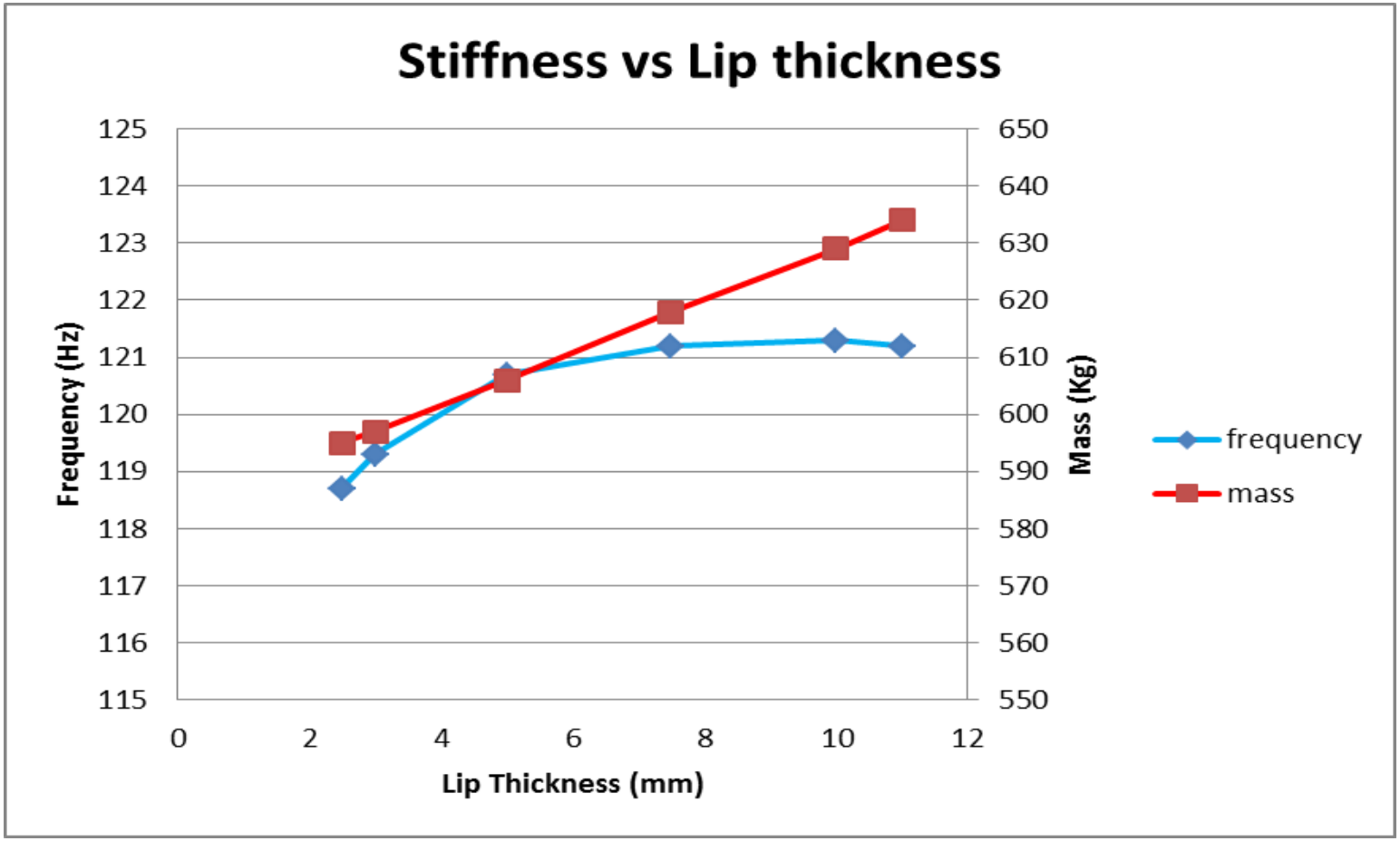
4 m Stiffness & Mass vs Facesheet Thickness

Increasing Facesheet thickness increases stiffness only to a point, then the stiffness deceases with additional thickness.



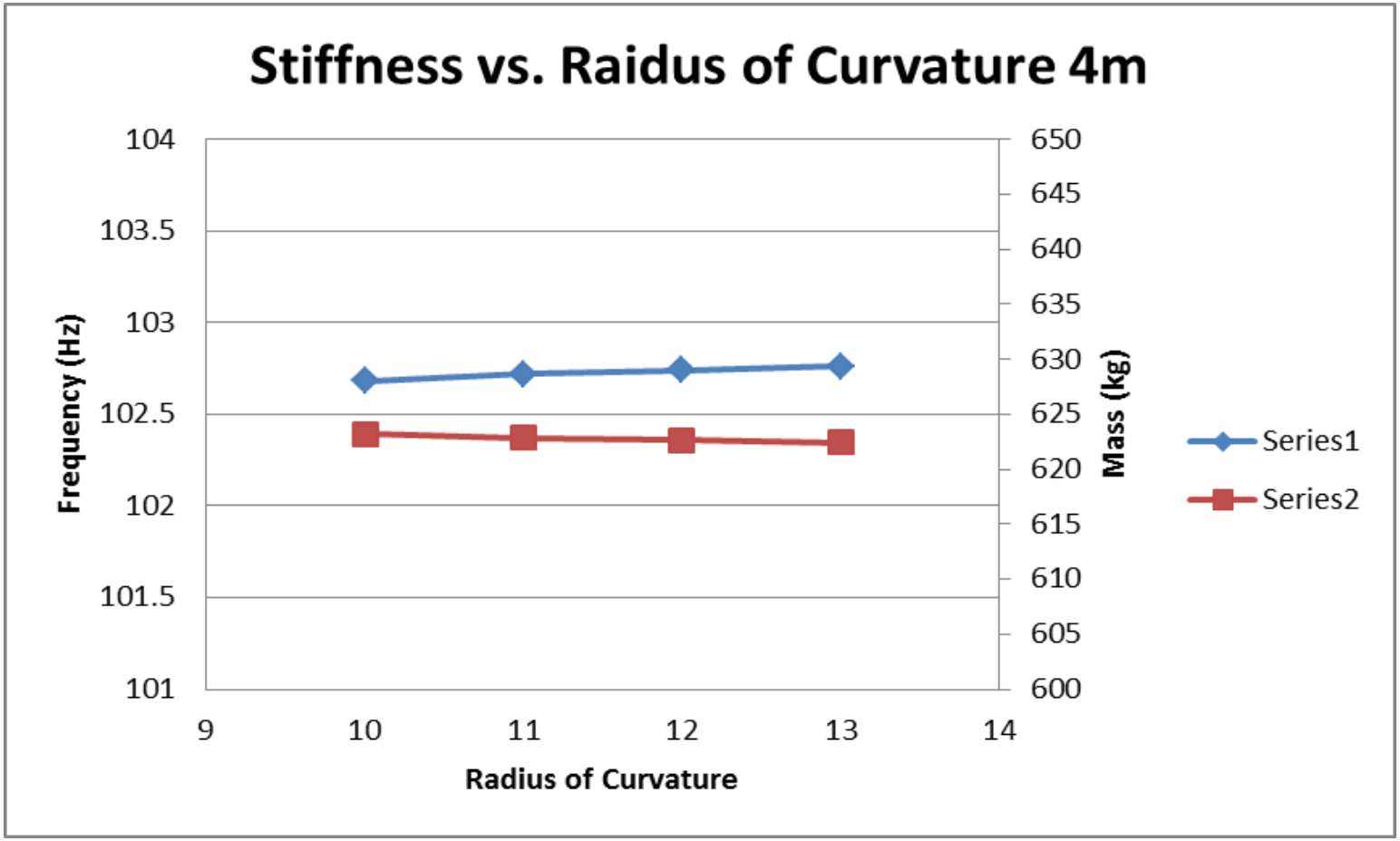
4 m Stiffness & Mass vs Internal Core Thickness

Increasing thickness of internal Core Elements results in minor stiffness increase.



4 m Stiffness & Mass vs Radius of Curvature

At 4 meter, Radius of Curvature has insignificant effect on Stiffness and Mass



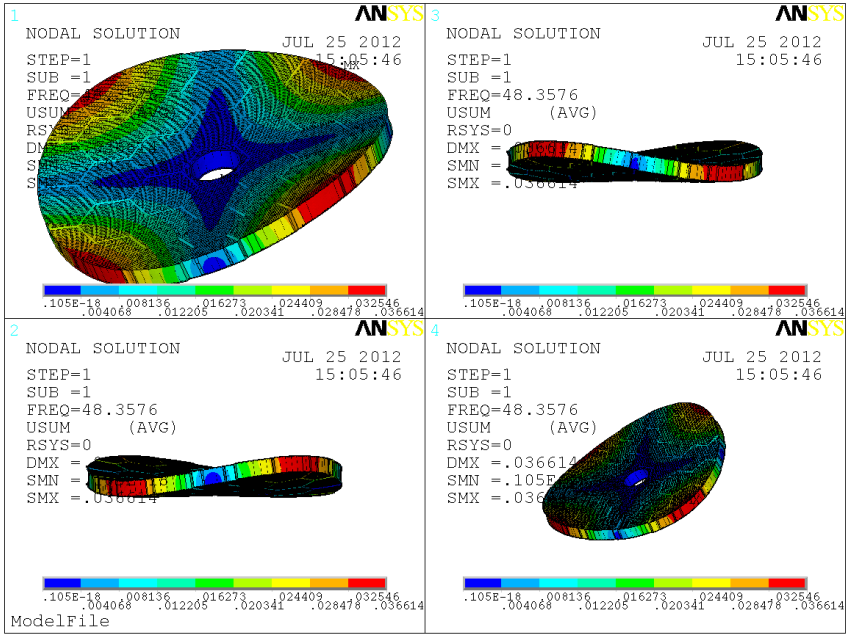
Parametric Trade Studies

8 meter

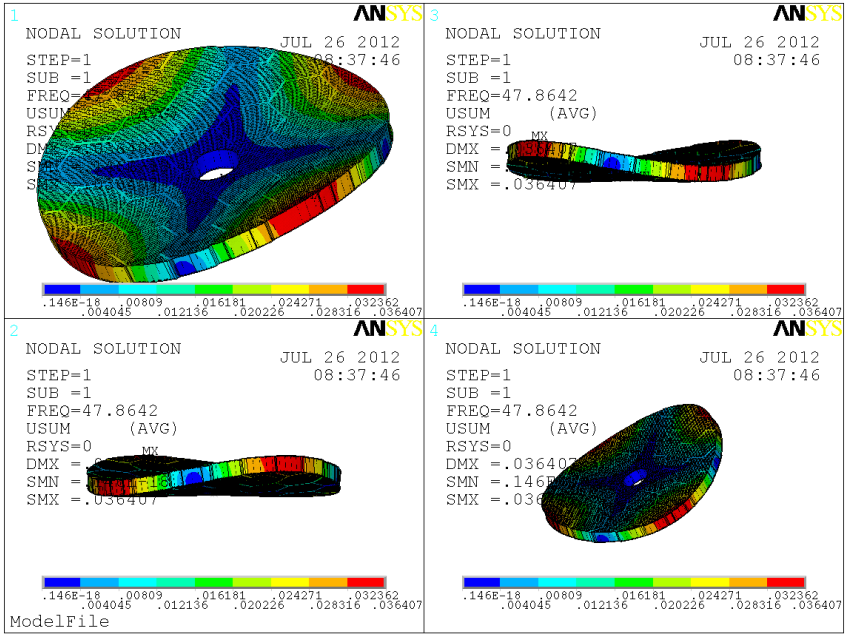
Symmetric vs. Offset

For a 8 meter, 500 mm thick mirror substrate, there is only minor differences between symmetric and off-set

Symmetric (48.3 Hz)

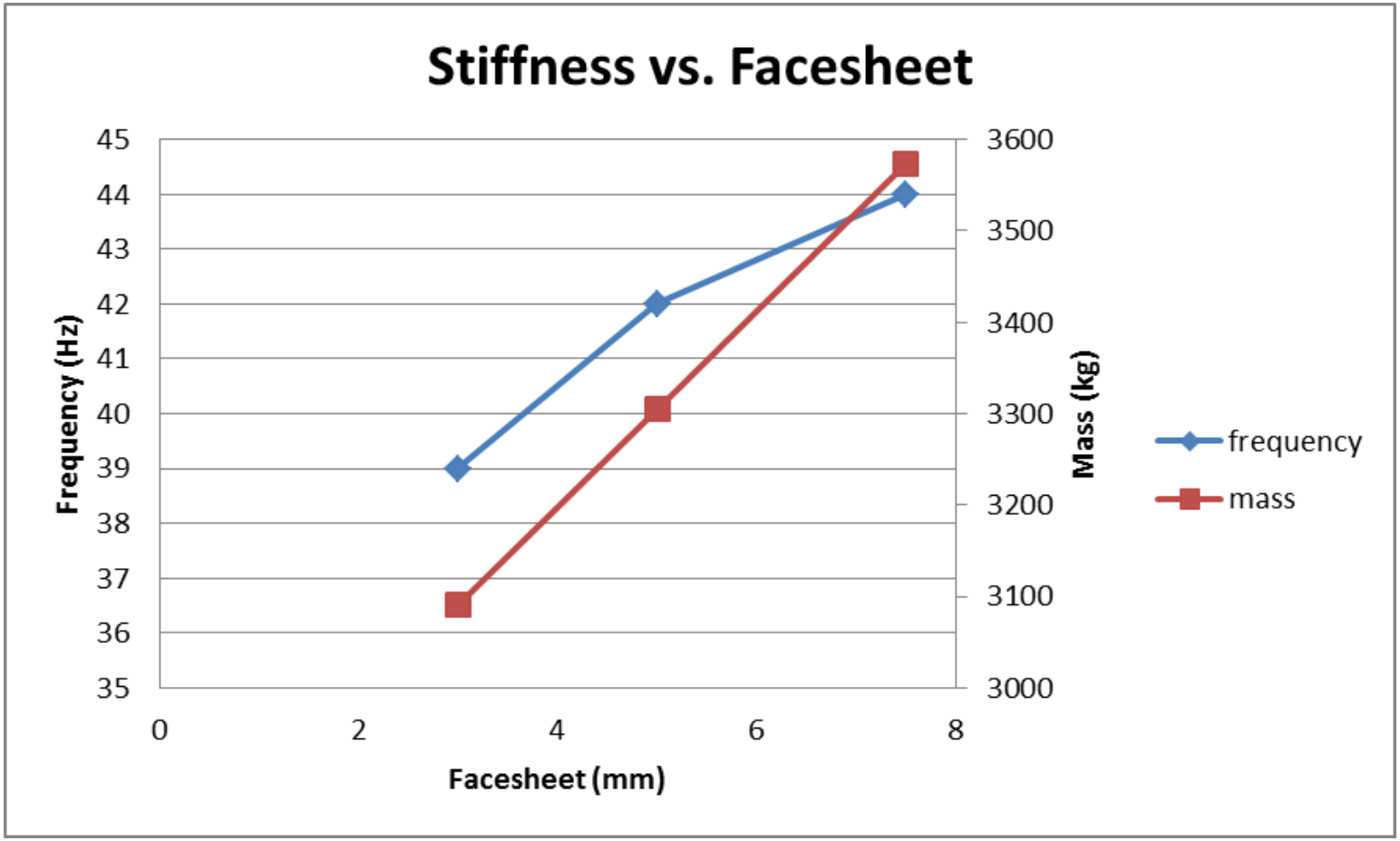


Offset (47.9 Hz)



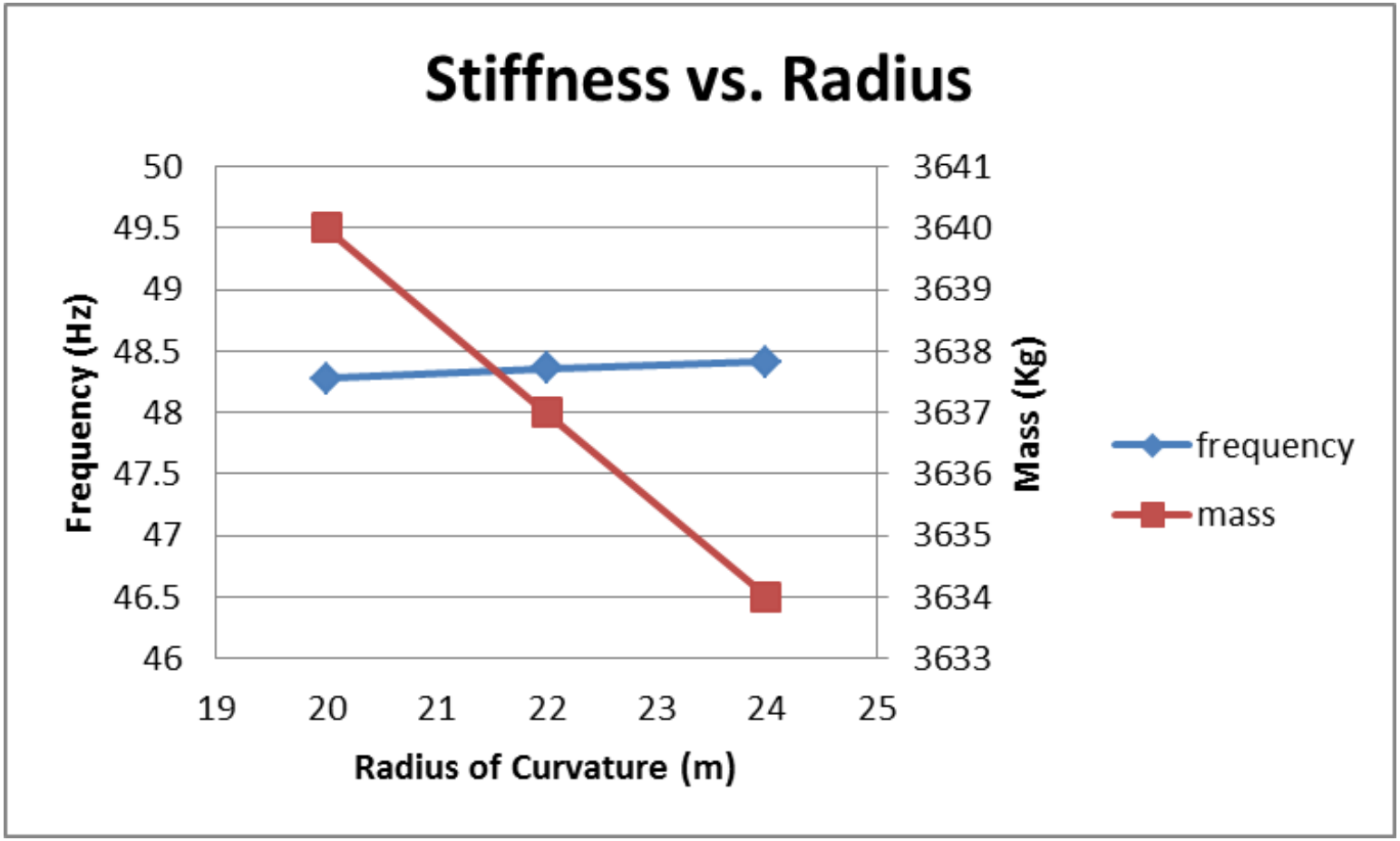
8 m Stiffness & Mass vs Facesheet Thickness

Increasing Facesheet thickness increases stiffness only to a point.



8 m Stiffness & Mass vs Radius of Curvature

At 8 meter, Radius of Curvature has an insignificant effect on Stiffness and Mass – plot is misleading mass change is 6 kg.



Conclusion

We have used the Arnold Lightweight Mirror Modeler tool to generate 4 point designs and several parameter trade studies.

These trade studies allow one manipulate design architectural elements to maximize mirror stiffness for mass constraint.

Tool allows one to generate a complete model and analysis in less than 60 minutes

Results Summary

4m Trade Study								
Architecture	Solid	Closed Back	Closed Back	Closed Back	Closed Back	Closed Back	Closed Back	Optimized
Mass	595 Kg	512 Kg	590 Kg	604 Kg	632 Kg	660 Kg	700 Kg	621 Kg
First Mode Frequency	8.2 Hz	101.4 Hz	115.0 Hz	117.5 Hz	120.9 Hz	122.9 Hz	136.3 Hz	124.5 Hz
Core Depth	N/A	30mm	40mm	40mm	40mm	40mm	50mm	40mm
Facesheet Thickness	22 mm	2.5 mm	2.5 mm	3 mm	4 mm	5 mm	2.5 mm	3 mm

8m Trade Study					
Architecture	Solid	Closed Back	Closed Back	Closed Back	Optimized
Mass	21801 Kg	3091 Kg	3305 Kg	3574 Kg	3637 Kg
First Mode Frequency	18.0 Hz	39.3 Hz	42.3 Hz	44.3 Hz	48.4 Hz
Core Depth	N/A	50 mm	50 mm	50 mm	50 mm
Facesheet Thickness	200 mm	3 mm	5 mm	7.5 mm	7 mm